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ECLSS Consumables Analysis

ALT Captive/Active 1 and Captive/Active 3

Mission Planning and Analysis Division

June 1977

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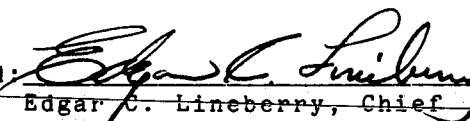
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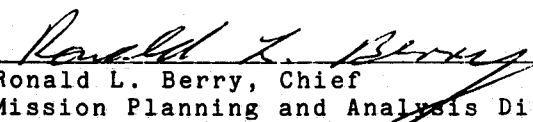
ALT CAPTIVE/ACTIVE 1 AND CAPTIVE/ACTIVE 3

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ECLSS CONSUMABLES ANALYSIS FOR
ALT CAPTIVE/ACTIVE 1 and CAPTIVE/ACTIVE 3

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1.0 SUMMARY

A consumables analysis of the environmental control and life-support system (ECLSS) has been performed for approach and landing test (ALT) captive/active missions 1 through 3 and is also applicable to missions 4 and 5. The ECLSS configuration analyzed and the guidelines and assumptions used in performing the analysis are presented. A projection of ammonia temperatures and pressures during the captive/active 1 mission is also included.

The resulting consumables budgets are presented in tabular and graphic form. Adequate margins were obtained for all systems.

2.0 INTRODUCTION

The ALT mission summary time lines have been updated and include significant revisions from those used for previous analyses. In addition, some component performance and cabin heat-leak data have been updated.

In accordance with the agreements contained in reference 1, nonpropulsive consumables analyses, using the revised input data, have been performed for captive/active missions 1 through 3. (Captive/active 3 results also apply to missions 4 and 5.) Consumables budgets have been prepared. In addition, a projection of temperature and pressure in the active thermal control system ammonia tanks has been prepared.

3.0 DISCUSSION

A current assessment of the status of ECLSS consumables budgets for the ALT program requires an analysis of the missions. The best defined information has been utilized to examine captive/active missions 1 through 5. These missions were analyzed as presented below. The resulting consumables budgets are discussed in section 4.0.

3.1 ECLSS System Configuration

The ALT system configuration used to perform the ECLSS consumables analysis is illustrated in figure 1. This configuration is based on data obtained from the requirements definition documents (refs. 2, 3, and 4) and the Shuttle Operational Data Book (ref. 5) as well as the best information obtained from subsystems design sources (ref. 6). Pertinent details of the configuration analyzed are as follows.

3.1.1 Active thermal control system.-

- a. The freon flow ratio between the aft cold plates and the interchanger is 13 and 87 percent, respectively.
- b. The freon flow ratio between the mid cold plates and the fuel cell heat exchanger is fixed at 6.2 and 93.8 percent, respectively.
- c. The ammonia (NH_3) storage system consists of six tanks, each with a maximum load capacity of 150 pounds, manifolded into two delivery systems. Each delivery system has an unusable quantity of 10.2 pounds.

3.1.2 Atmospheric revitalization system water loop.- The water flow ratio between the three avionics bays is fixed at 37, 36, and 27 percent for bays 1, 2, and 3, respectively.

3.1.3 Atmospheric revitalization system atmospheric loop.-

- a. No atmospheric oxygen and nitrogen supplies are carried on ALT missions.
- b. No carbon dioxide removal systems are considered.
- c. The pressurized cabin volume is 2450 ft³.

3.1.4 Potable and waste storage systems.-

- a. Fuel cell water production is stored in two Apollo-type waste-water tanks, each having a volumetric capacity of 57 ± 2 pounds. The tanks are manifolded together. Although no specific data on unusable capacity are published for the ALT application, these tanks had a 4-pound unusable capacity when used on the Apollo

Program with the ullage bladder vented. Since the ullage bladder is to be vented into the cabin on OV101, the same 4-pound unusable capacity is assumed.

b. Condensate transferred from the atmospheric revitalization system cabin heat exchanger is stored in one Apollo-type glycol reservoir having a capacity of 7.5 ± 0.2 pounds.

3.2 Guidelines and Assumptions

Assumptions and guidelines utilized in this analysis are presented in the following subsections.

3.2.1 Active thermal control system.-

- a. Both freon loops are operating in parallel.
- b. Freon flow rate is 2950 lb/hr per loop.
- c. The ammonia boiler controls freon discharge temperature to $35 \pm 3^\circ$ F.
- d. Ammonia boiler heat-rejection capability is based on NH_3 heat absorption of 520 Btu/lb. This value assumes an NH_3 storage temperature of 95° F.
- e. When both NH_3 storage banks are supplying the NH_3 boiler, the NH_3 flow is divided equally between the two banks.
- f. Ammonia loaded initially is 406 lb per bank, based on a loading temperature of 90° F.

3.2.2 Atmospheric revitalization system water loop.-

- a. Both water loops are operating in parallel.
- b. Water pump flow rate is 1500 lb/hr per loop.
- c. The flow rate through the interchanger water bypass line is set at 805 lb/hr per loop.

3.2.3 Atmospheric revitalization system atmospheric loop.-

- a. There are two crewmen on each mission, each having a nominal metabolic rate of 525 Btu/hr.
- b. Crew metabolic output (CO_2 , sensible and latent heat) is added to the cabin atmosphere.
- c. Cabin leakage rate at 14.7 psid is 7.0 lb/day (1.68 lb/day of O_2 , 5.32 lb/day of N_2).
- d. Initial atmospheric conditions are as follows:

Temperature	530° R
Pressure	13.4 psia (2300 feet, altitude)
Dewpoint	510.5° R

e. Exhaust gas from the crew facemasks will flow into the cabin.

f. The cabin fan flow rate is 1590 lb/hr.

g. During ascent, cabin pressure is vented down to 10.5 psia before the dump valve is closed. The cabin is repressurized from the ambient atmosphere through the negative pressure relief valve during descent.

3.2.4 Potable and waste water storage subsystem.- Fuel cell water is produced at a rate of 0.826 lb/hr per kW of fuel cell output (ref. 5).

3.3 Analysis

The ECLSS consumables analysis of the ALT missions is performed using the Shuttle environmental consumables requirements evaluation tool (SECRET) computer program. This program utilizes the Fortran environmental analysis routines (FEAR)(ref. 7) to model the ECLSS system and components. Model accuracy is considered to be ± 10 percent.

Input data used for the analysis consisted of the following:

a. An events time line was obtained from reference 1 as modified by information derived from reference 8. Pertinent events are as follows:

Event	Times, minutes from T ₀		
	CA-1	CA-2	CA-3
Begin analysis	-90	-90	-90
NH ₃ boiler system B on	-87	-87	-87
Fuel cells transfer to internal reactants	-85	-85	-85
NH ₃ boiler system A on, B off	-84	-84	-84
NH ₃ boiler system A off, B on	-11	-11	-11
SCA start takeoff roll	0	0	0
SCA landing	+60	+63	+55
Power off (end of analysis)	+91	+94	+86

b. Electrical power loads were obtained from reference 9, as transmitted on computer tape X09901 and adjusted for the latest time line. Additionally, the fuel cells are assumed to be operating on ground-supplied reactants from T-3 hours 15 minutes until T-1 hour 25 minutes at an average output of 15.7 kW (ref. 8). Data accuracy is considered to be ± 2.5 percent.

c. The ambient pressure profile was constructed from data contained in reference 10.

d. A structural heat leak as defined in table IX of reference 6 was included in the analysis.

e. Contingency requirements in the ammonia system have been defined for a 20-minute return reserve. The reserve is the amount of ammonia required in bank A, after an in-flight loss of bank B, to support the orbiter through a 20-minute return to the landing site and subsequent powerdown. The requirement was considered to be identical to the ammonia consumption during the final 20 minutes of a nominal flight and subsequent powerdown.

3.4 Ammonia Pressure and Temperature

As requested in reference 1, a projection of ammonia pressure and temperature, as a function of mission time, has been developed. A range of data, as a function of hot and cold ambient conditions at Edwards AFB and the captive/active mission 1 time line, has been prepared. These projections are presented in figure 20 and 21.

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4.0 RESULTS AND CONCLUSIONS

The results of the analysis are summarized in tables 1 through 3 and figures 2 through 19. All consumables (condensate storage, fuel cell water storage, and ammonia) have adequate margins for the contingencies and reserves considered.

It is apparent from the tables that the longest mission (captive/active 2) has the smallest margins, and on all missions, ammonia margins are the limiting factor. During a normal mission, ammonia bank B would have margins equivalent to 27.1 to 36.8 minutes of operation, depending on the mission. In case of a failure in bank B, bank A would have margins equivalent to 17.3 minutes of operation.

It is noteworthy that the analysis performed using the latest flow rate and heat transfer data indicates a marginal ability to control cabin temperature to 70° F (figs. 5, 11, and 17). This is due primarily to the high water flow rate (1610 lb/hr) through the interchanger.

5.0 REFERENCES

1. Flight Operations Directorate/Flight Control Division: ALT Consumables - CF7(77-58), Apr. 20, 1977.
2. Rockwell International: Requirements/Definition Document - Atmospheric Revitalization System, SD72-SH-0106-1, Oct. 1, 1976.
3. Rockwell International: Requirements/Definition Document - Food, Water & Waste, SD72-SH-0106-2, June 15, 1976.
4. Rockwell International: Requirements/Definition Document - Active Thermal Control, SD72-SH-0106-3, July 15, 1976.
5. Operational Data Branch: Shuttle Operational Data Book, Vol. I - Shuttle Systems Performance and Constraints Data, JSC-08934, Amendment 49, Dec. 3, 1976.
6. Engineering and Development/Crew Systems Division: Orbiter OV101 ECLSS Configuration and Characteristics Data for Use in Consumables and Thermal Analyses, EC2-77-086, May 2, 1977.
7. TRW: Transmittal of Fortran Environmental Analysis Routines (FEAR) Documentation, TRW Memo No. 6533.5-73-41, June 1974.
8. Telecon: G. Sinclair/RI and H. Kolkhorst/FM2, Revision of Start-up Timeline on ALT Captive/Active Missions, May 4, 1977.
9. Mission Planning and Analysis Division: EPS Consumables Analysis for ALT Captive/Active 1 and Captive/Active 3, FM26-77-13, January 17, 1977.
10. McDonnell Douglas Technical Services Co.: APU/Hydraulics Water Consumables Analysis for ALT, TM 1.4-7-337, Oct. 29, 1976.

TABLE I.- ECLSS CONSUMABLES BUDGET FOR ALT CAPTIVE/ACTIVE 1

Nonpropulsive consumables	Condensate	Fuel cell	Ammonia supply, lb	
	water tank, lb	water tank, lb	Bank A	Bank B
al capacity (H ₂ O) or total aded (NH ₃)	7.5	114.0	406.0	406.0
Unusables - residual	--	8.0	10.2	10.2
Total usable	7.5	106.0	395.8	395.8
Reserves				
Dispersion and flight-planning uncertainty (15 percent)	0.13	9.7	28.5	41.2
Available for nominal mission	7.37	96.3	367.3	354.6
Flight requirement	0.88	64.3	190.1	275.0
20-minute return contingency	--	--	132.3	--
Margin, pounds	6.49	32.0	44.9	79.6
Margin, minutes ^a	847.0	142.2	17.3	30.6

^aAssumes normal usage rate.

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TABLE II.- ECLSS CONSUMABLES BUDGET FOR ALT CAPTIVE/ACTIVE 2

Nonpropulsive consumables	Condensate	Fuel cell	Ammonia supply, lb	
	water tank, lb	water tank, lb	Bank A	Bank B
Total capacity (H ₂ O) or total loaded (NH ₃)	7.5	114.0	406.0	406.0
Unusables - residual	--	8.0	10.2	10.2
Total usable	7.5	106.0	395.8	395.8
Reserves				
Dispersion and flight-planning uncertainty (15 percent)	0.14	9.8	28.5	42.4
Available for nominal mission	7.36	96.2	367.3	353.4
Flight requirement	0.90	65.1	190.1	282.8
20-minute return contingency	--	--	132.3	--
Margin, pounds	6.46	31.1	44.9	70.6
Margin, minutes ^a	843.0	138.2	17.3	27.1

^aAssumes normal usage rate.

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TABLE III.- ECLSS CONSUMABLES BUDGET FOR ALT CAPTIVE/ACTIVE 3 through 5

<u>Nonpropulsive consumables</u>	Condensate	Fuel cell	<u>Ammonia supply, lb</u>	
	water tank, lb	water tank, lb	<u>Bank A</u>	<u>Bank B</u>
al capacity (H ₂ O) or total oaded (NH ₃)	7.5	114.0	406.0	406.0
Unusables - residual	--	8.0	10.2	10.2
Total usable	7.5	106.0	395.8	395.8
Reserves				
Dispersion and flight-planning uncertainty (15 percent)	0.13	9.5	28.5	39.1
Available for nominal mission	7.37	96.5	367.3	356.7
Flight requirement	.84	63.1	190.1	260.9
20-minute return contingency	--	--	132.3	--
Margin, pounds	6.53	33.4	44.9	95.8
Margin, minutes ^a	852.	148.4	17.3	36.8

^a Assumes normal usage rate.

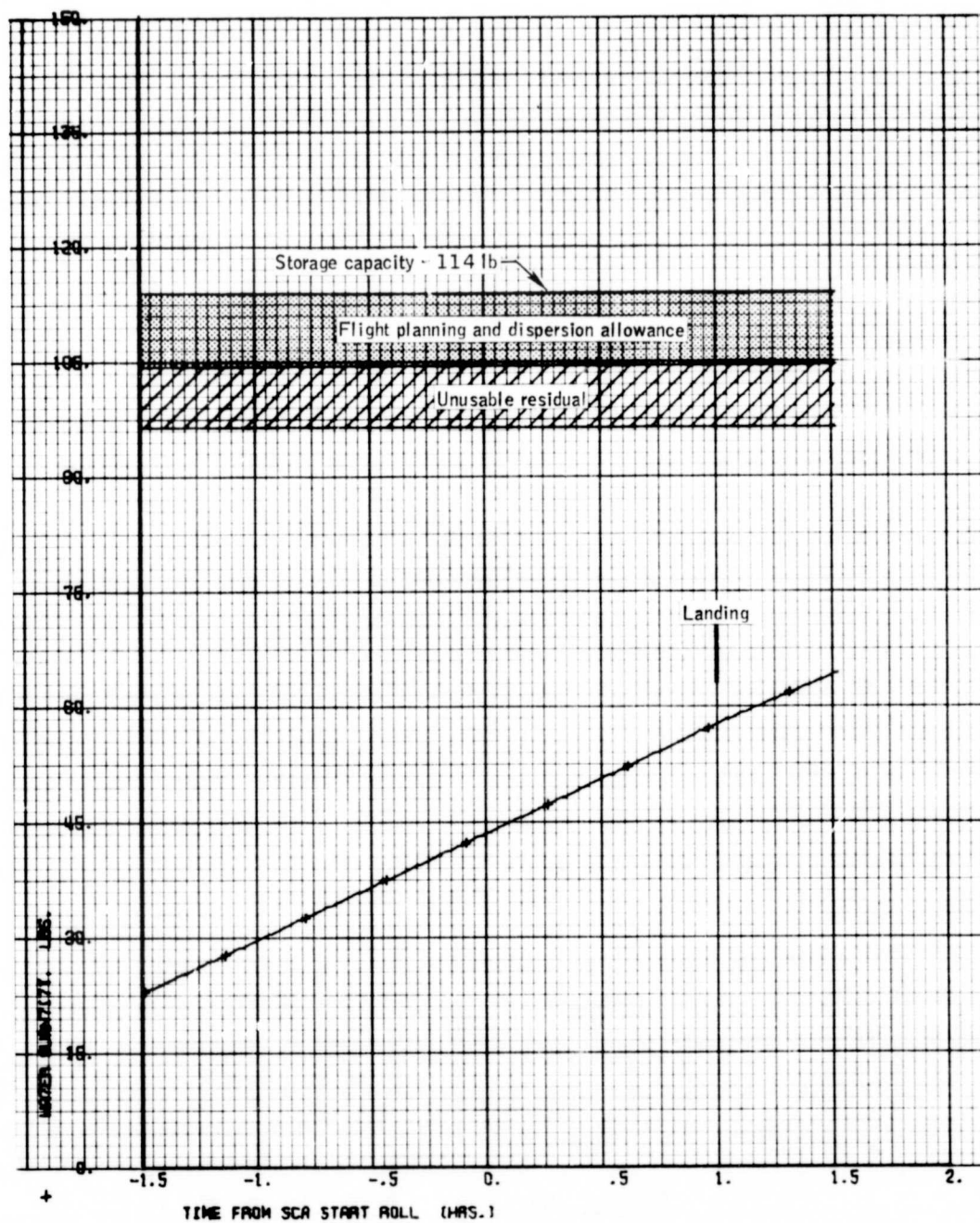


Figure 2.- Accumulated fuel cell water for ALT captive/active mission 1.

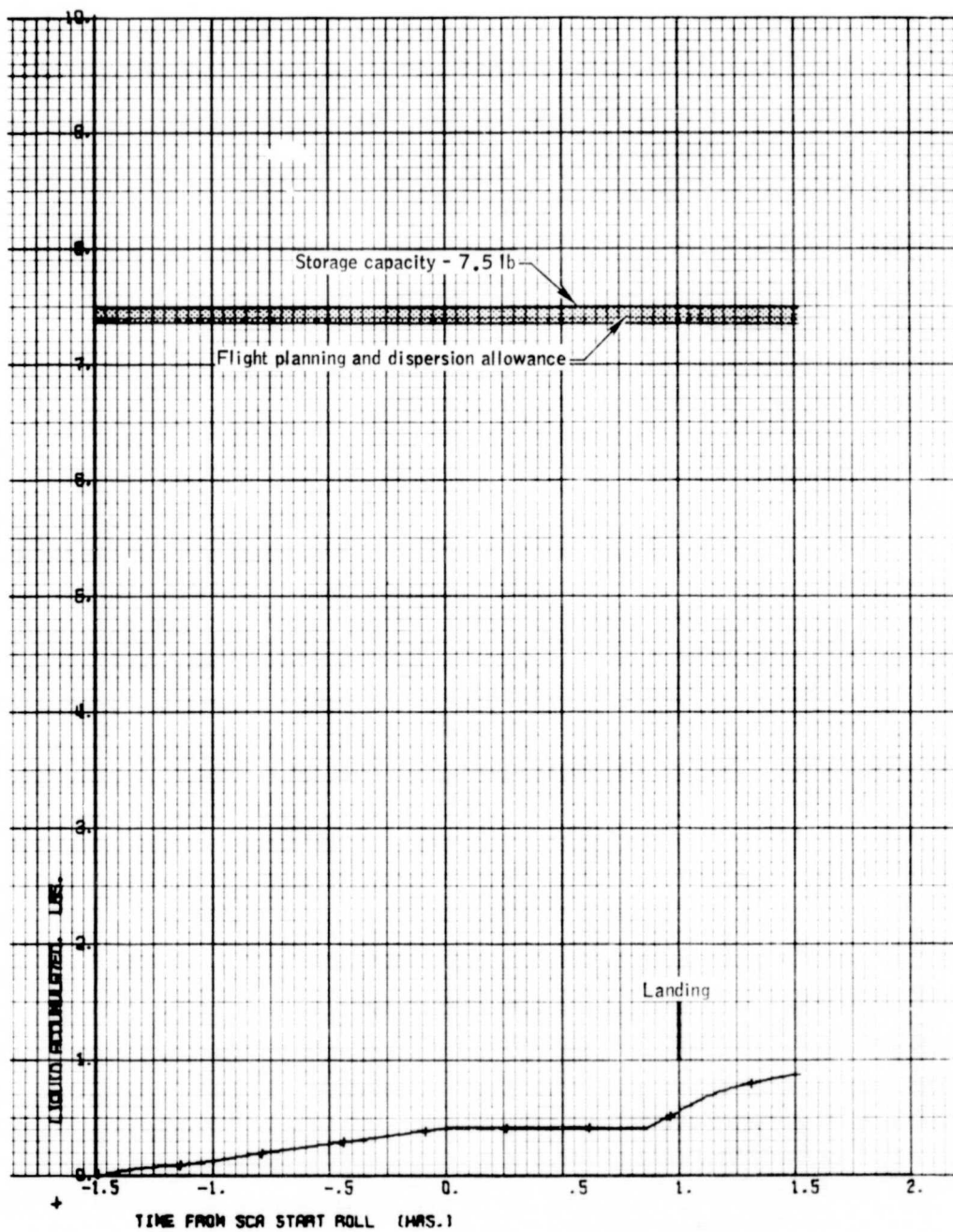


Figure 3.- Accumulated condensate water for ALT captive/active mission 1.

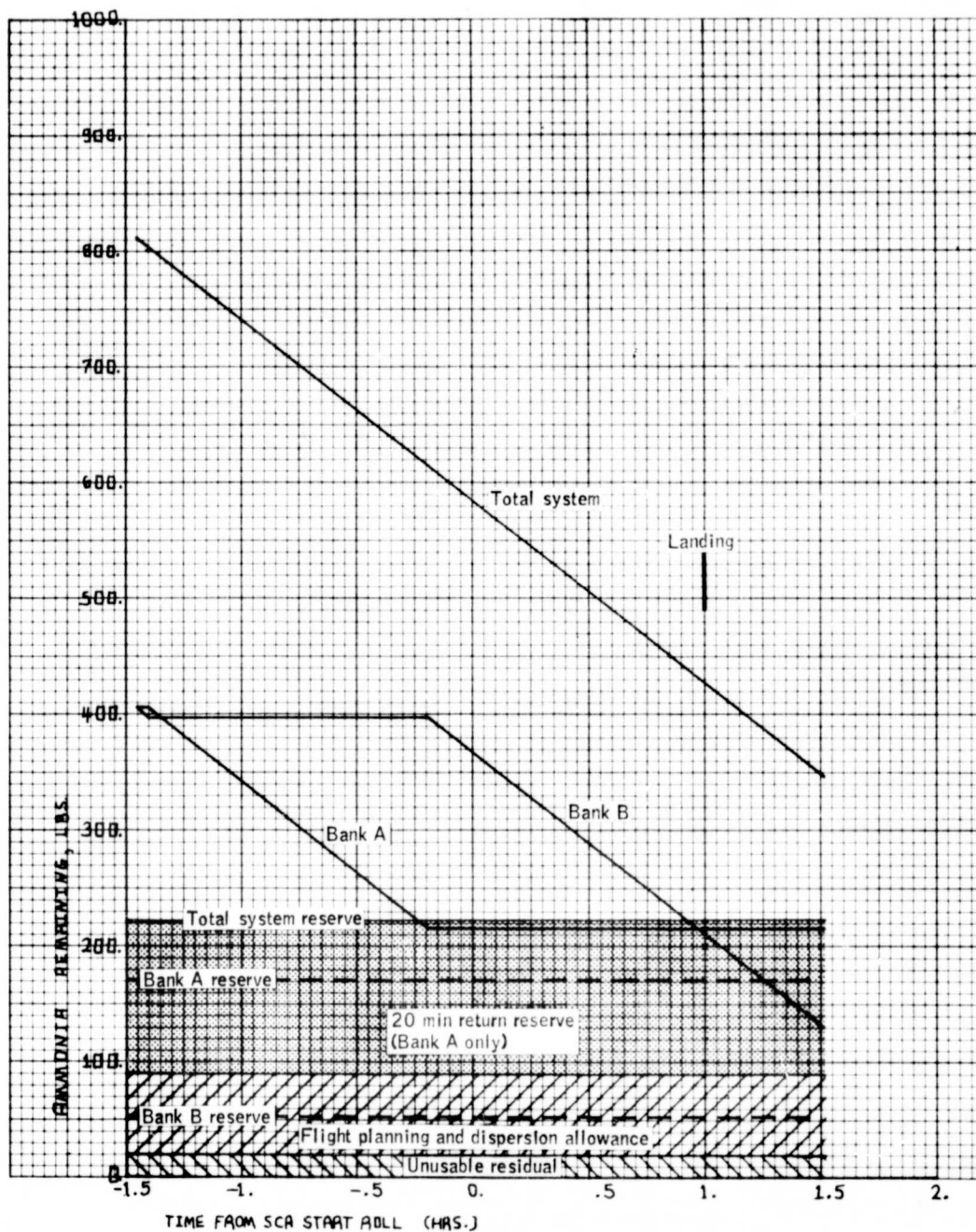


Figure 4.- Ammonia remaining for ALT captive/active mission 1.



Figure 5.- Orbiter cabin atmospheric conditions for ALT captive/active mission 1.

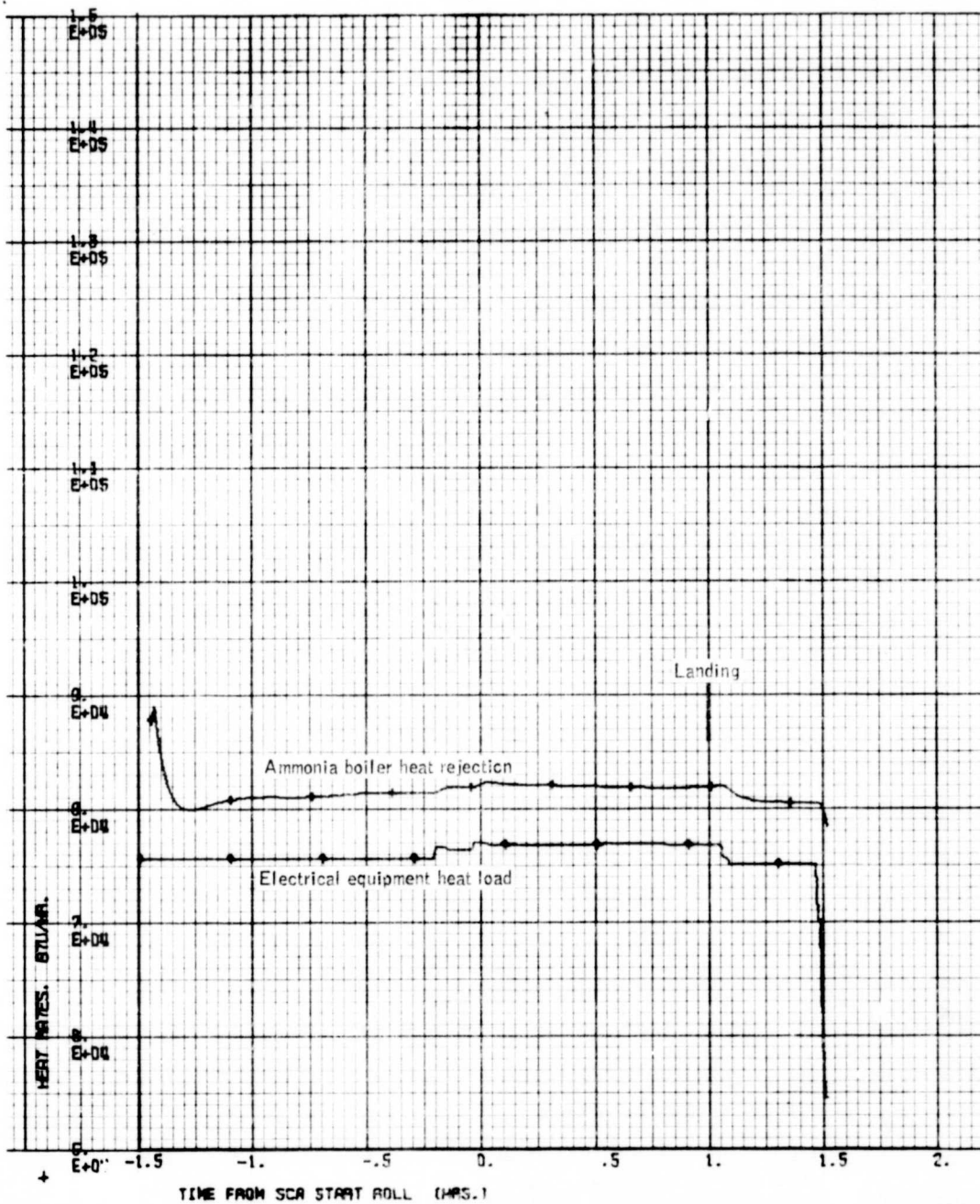


Figure 6.- Orbiter heat load and heat rejection for ALT captive/active mission 1.

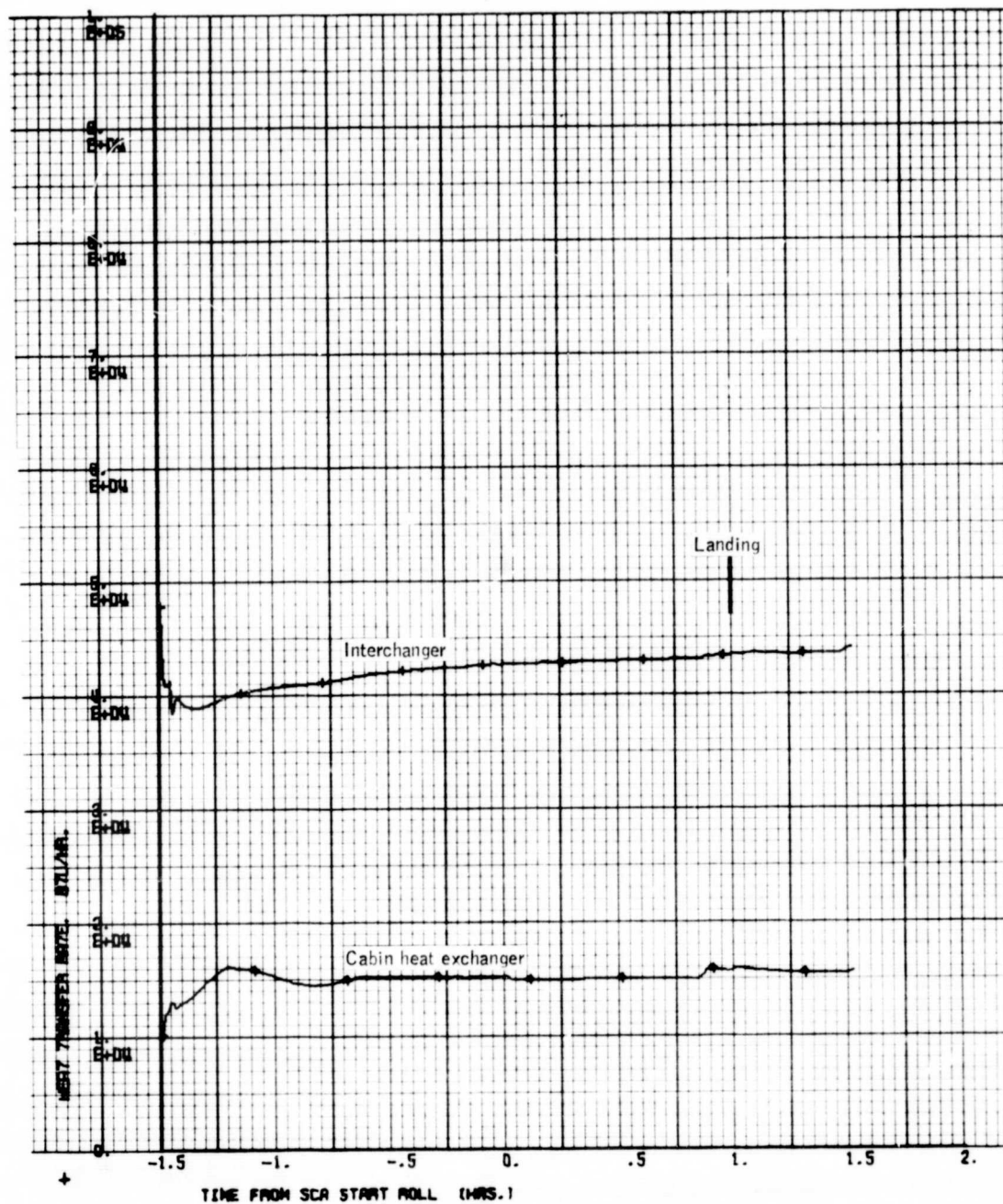


Figure 7.- ECLSS internal heat transfer rate for ALT captive/active mission 1.

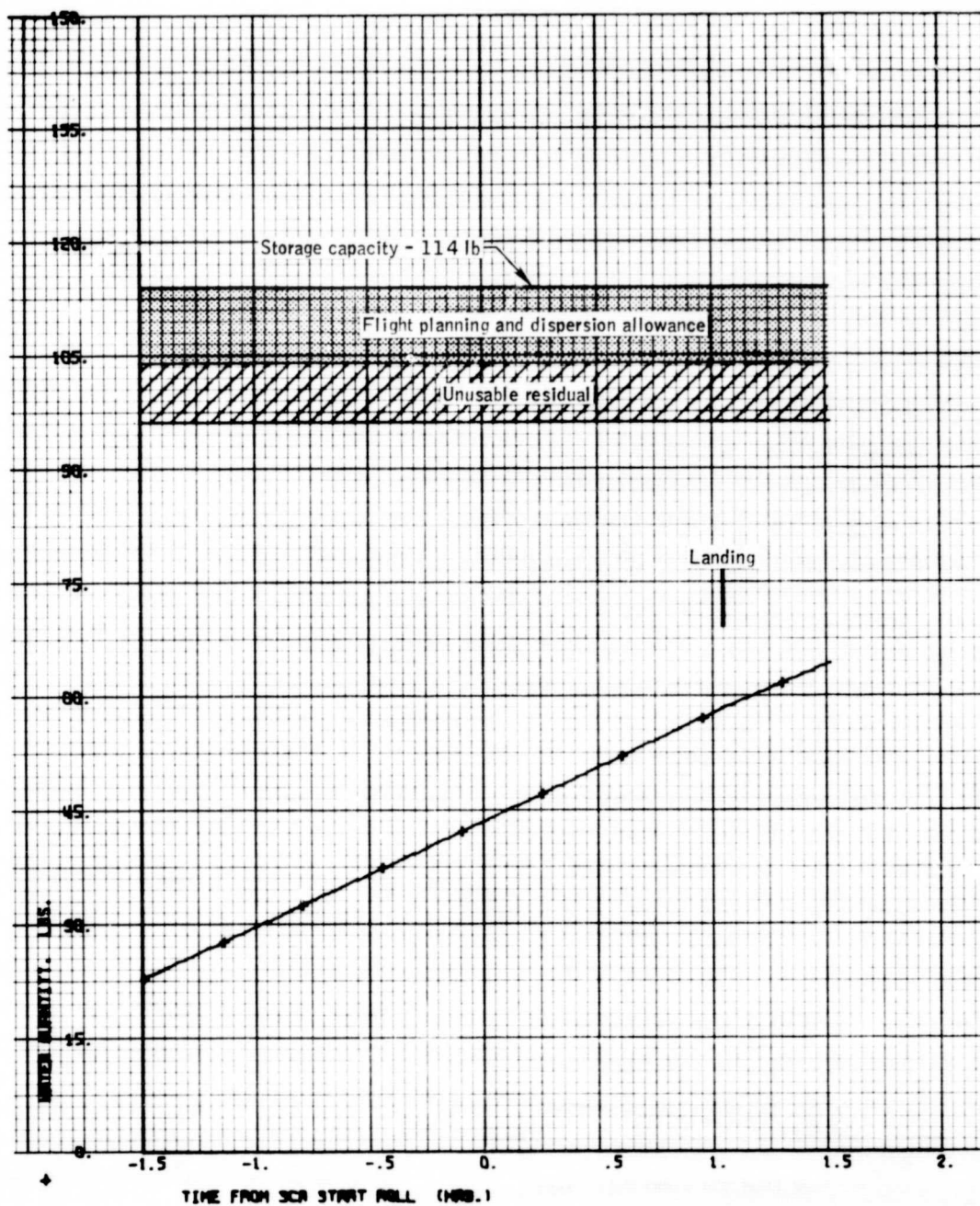


Figure 8.- Accumulated fuel cell water for ALT captive/active mission 2.

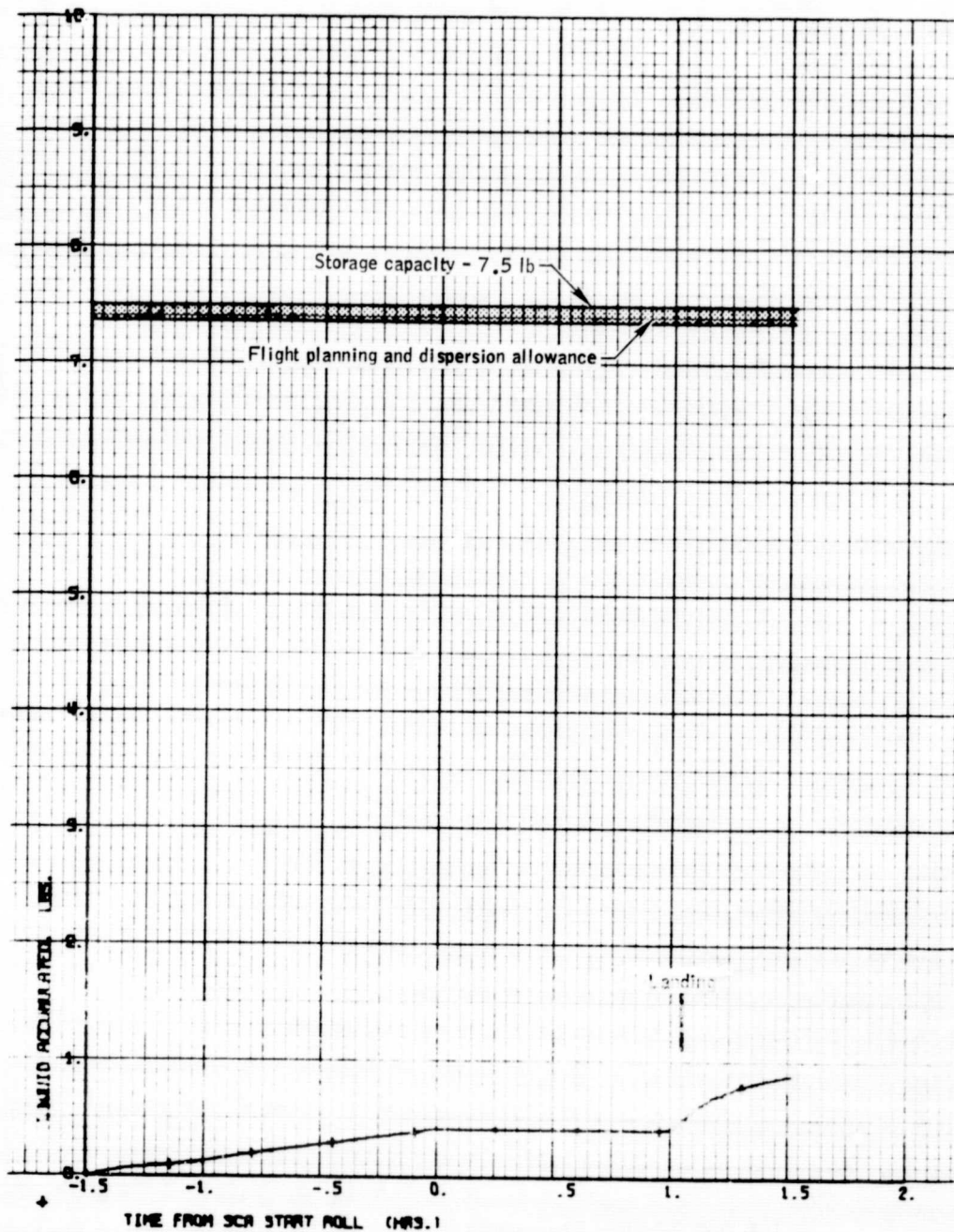


Figure 9.- Accumulated condensate water for ALT captive/active mission 2.

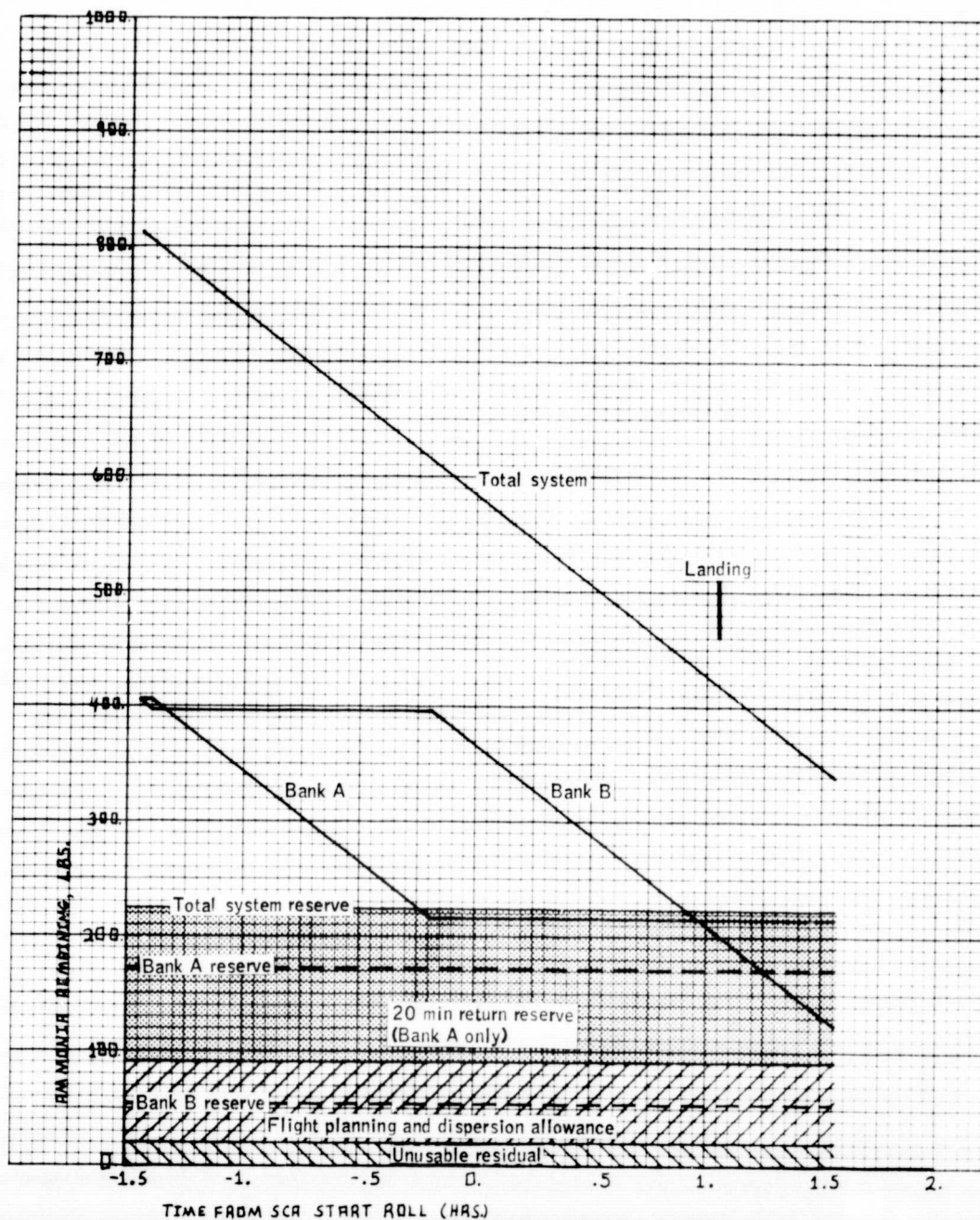


Figure 10.- Ammonia remaining for ALT captive/active mission 2.

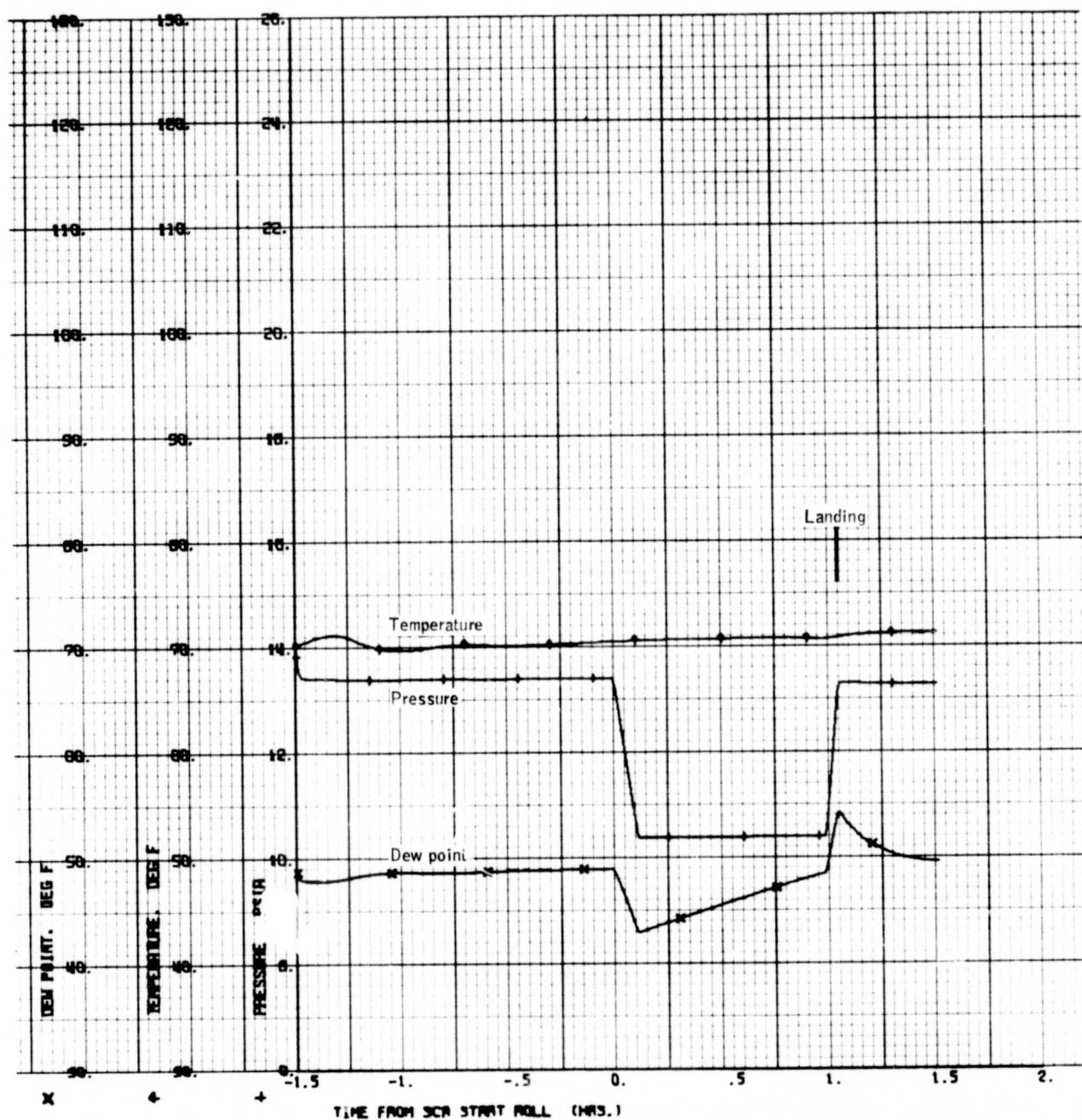


Figure 11.- Orbiter cabin atmospheric conditions for ALT captive/active mission 2.

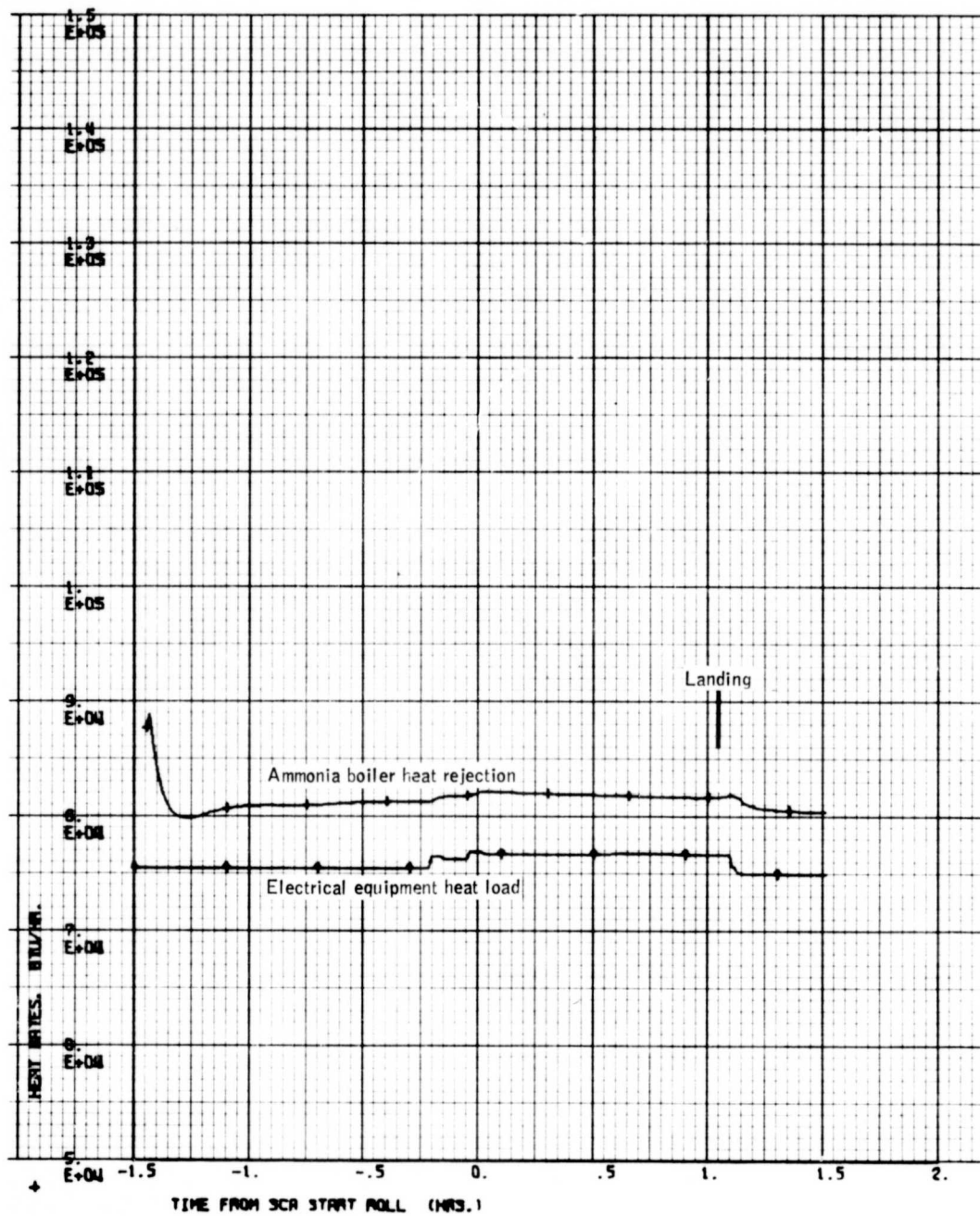


Figure 12.- Orbiter heat load and heat rejection for ALT captive/active mission 2.

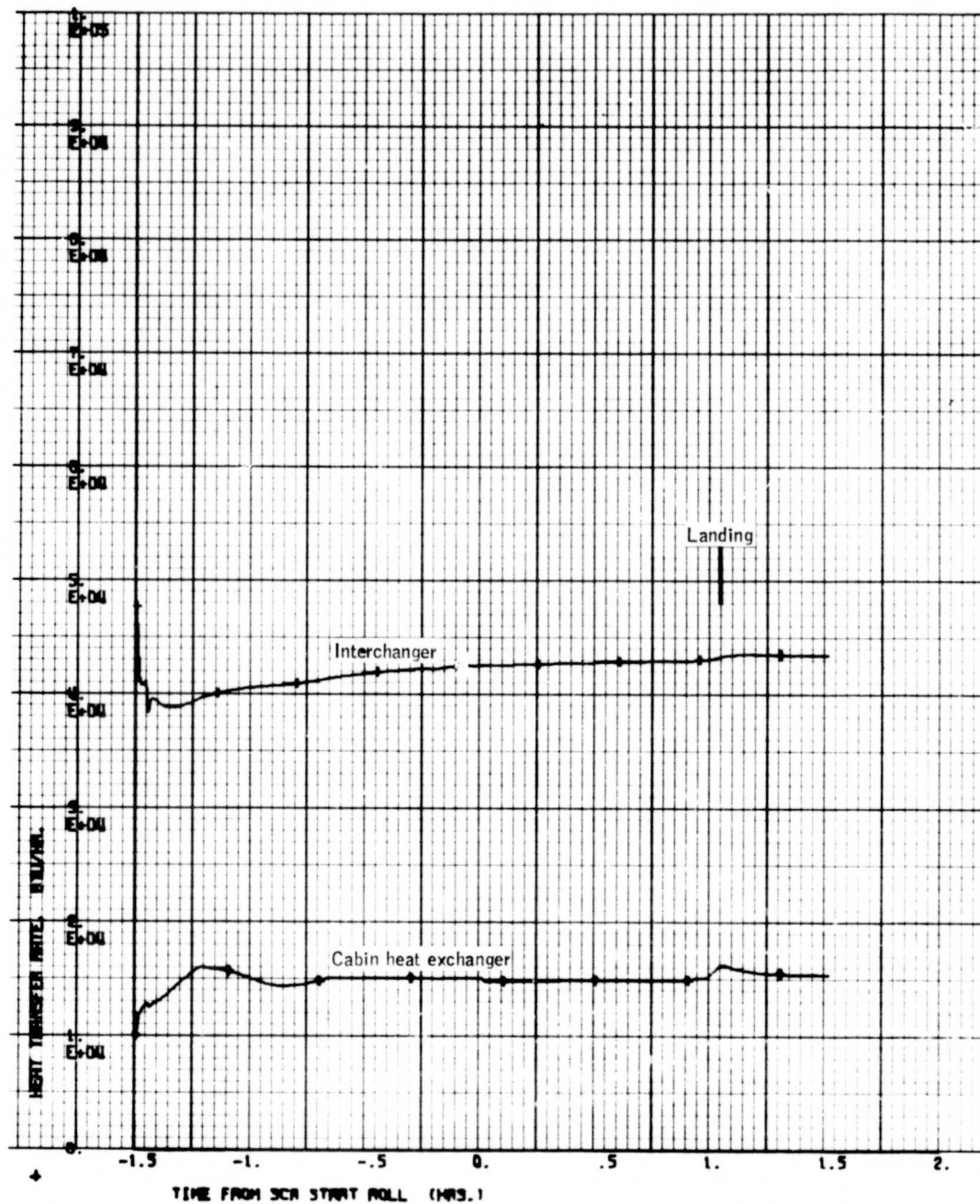


Figure 13.- ECLSS internal heat transfer rate for ALT captive/active mission 2.

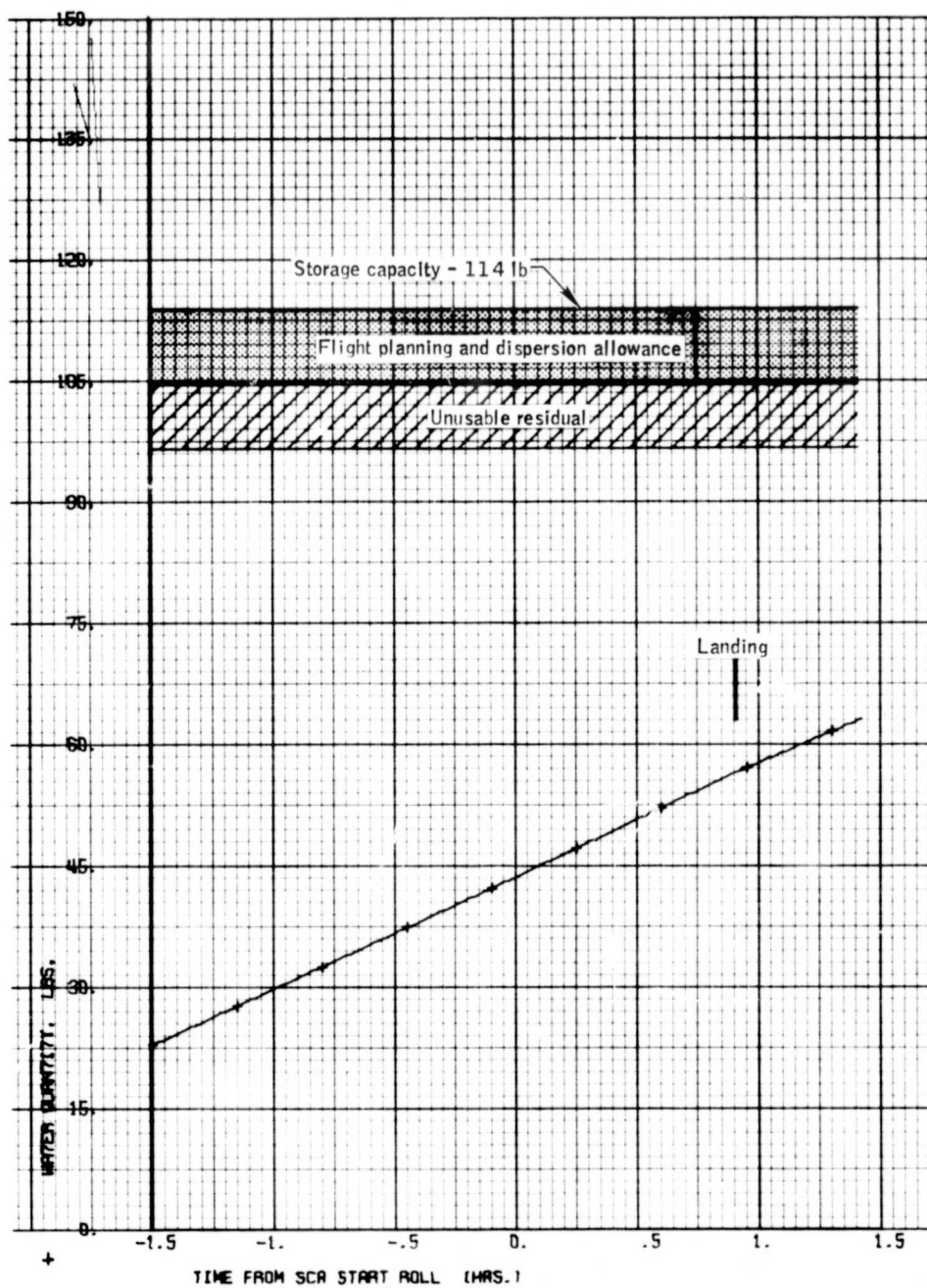


Figure 14.- Accumulated fuel cell water for ALT captive/active mission 3.

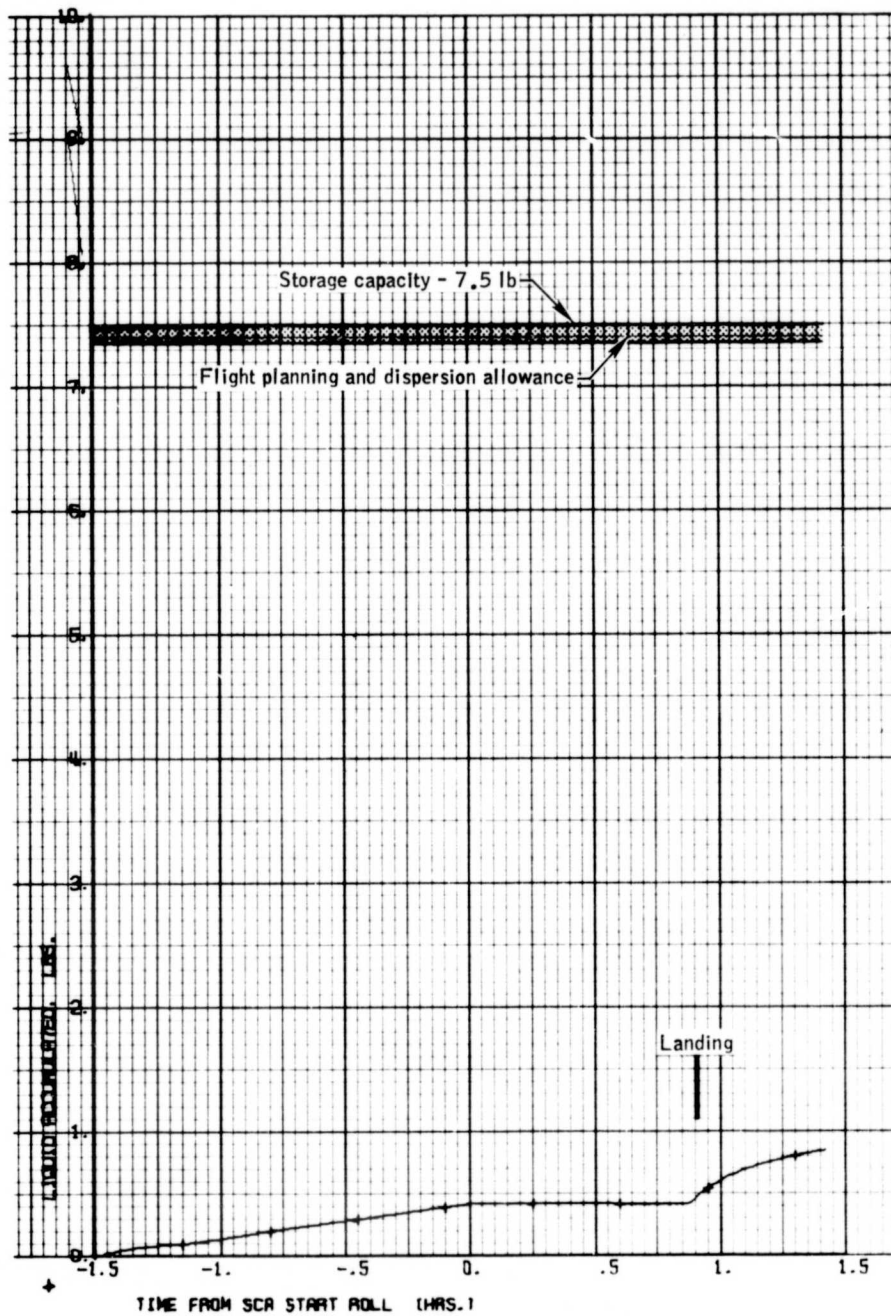


Figure 15.- Accumulated condensate water for ALT captive/active mission 3.

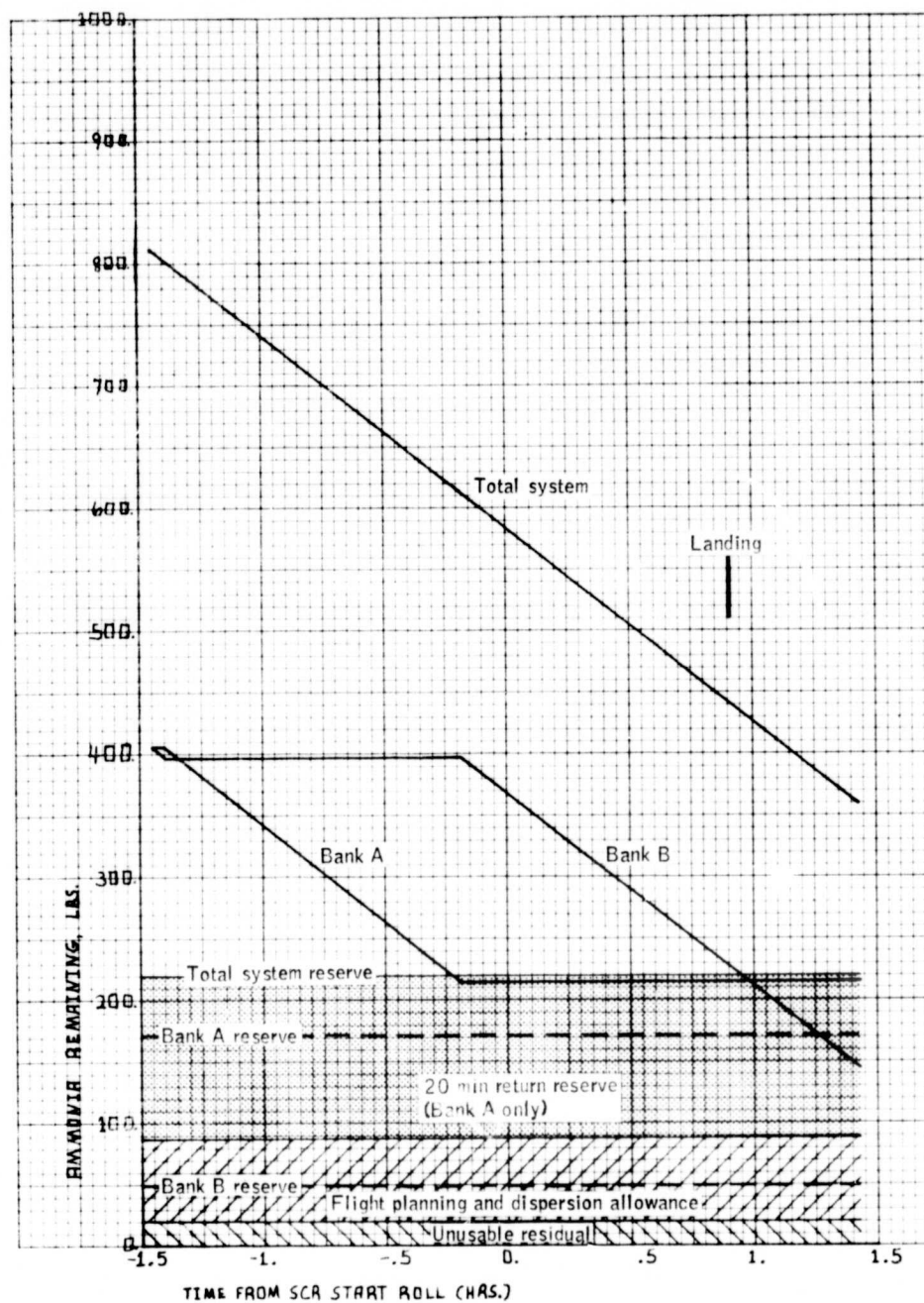


Figure 16.- Ammonia remaining for ALT captive/active mission 3.

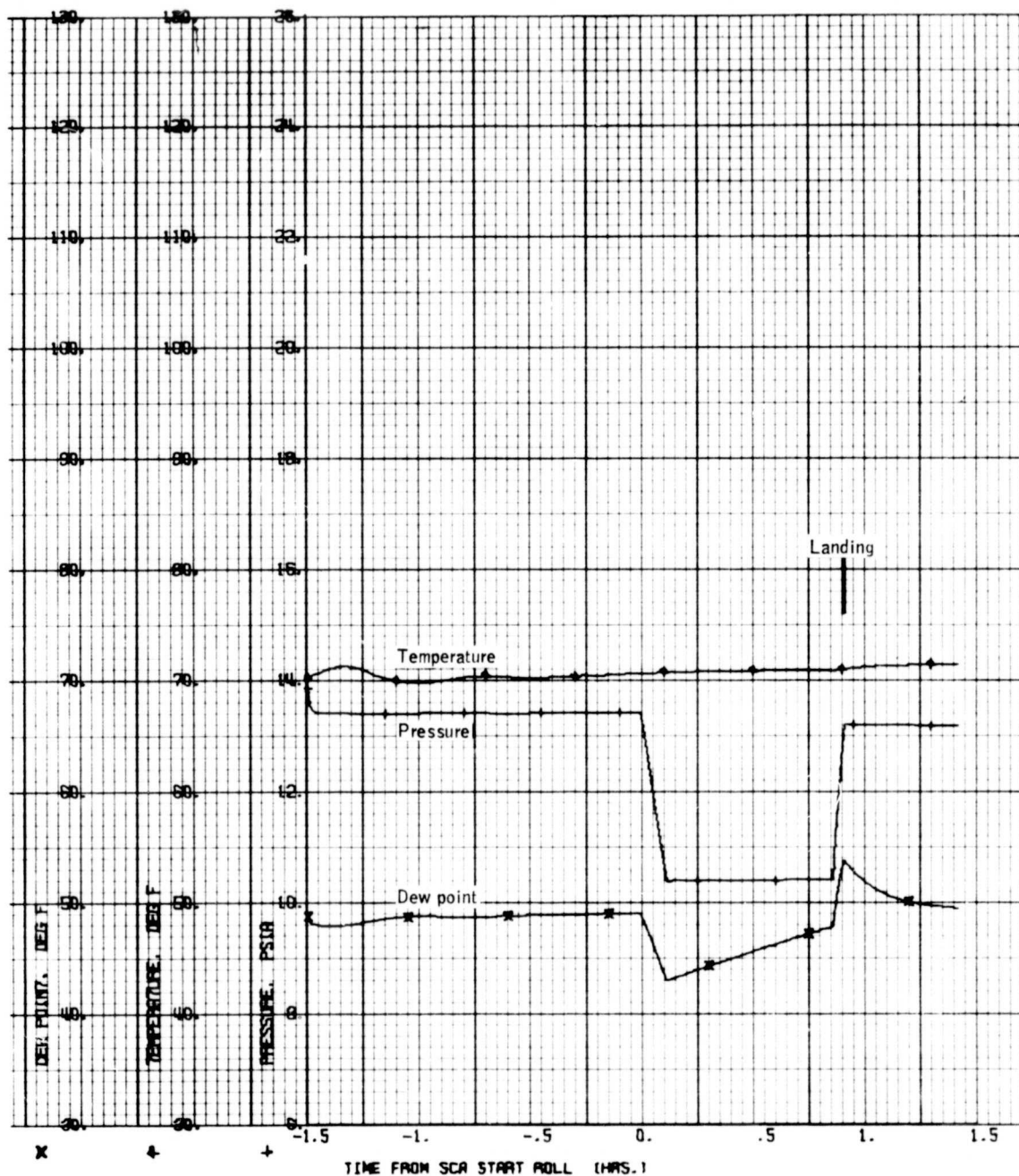


Figure 17.- Orbiter cabin atmospheric conditions for ALT captive/active mission 3.

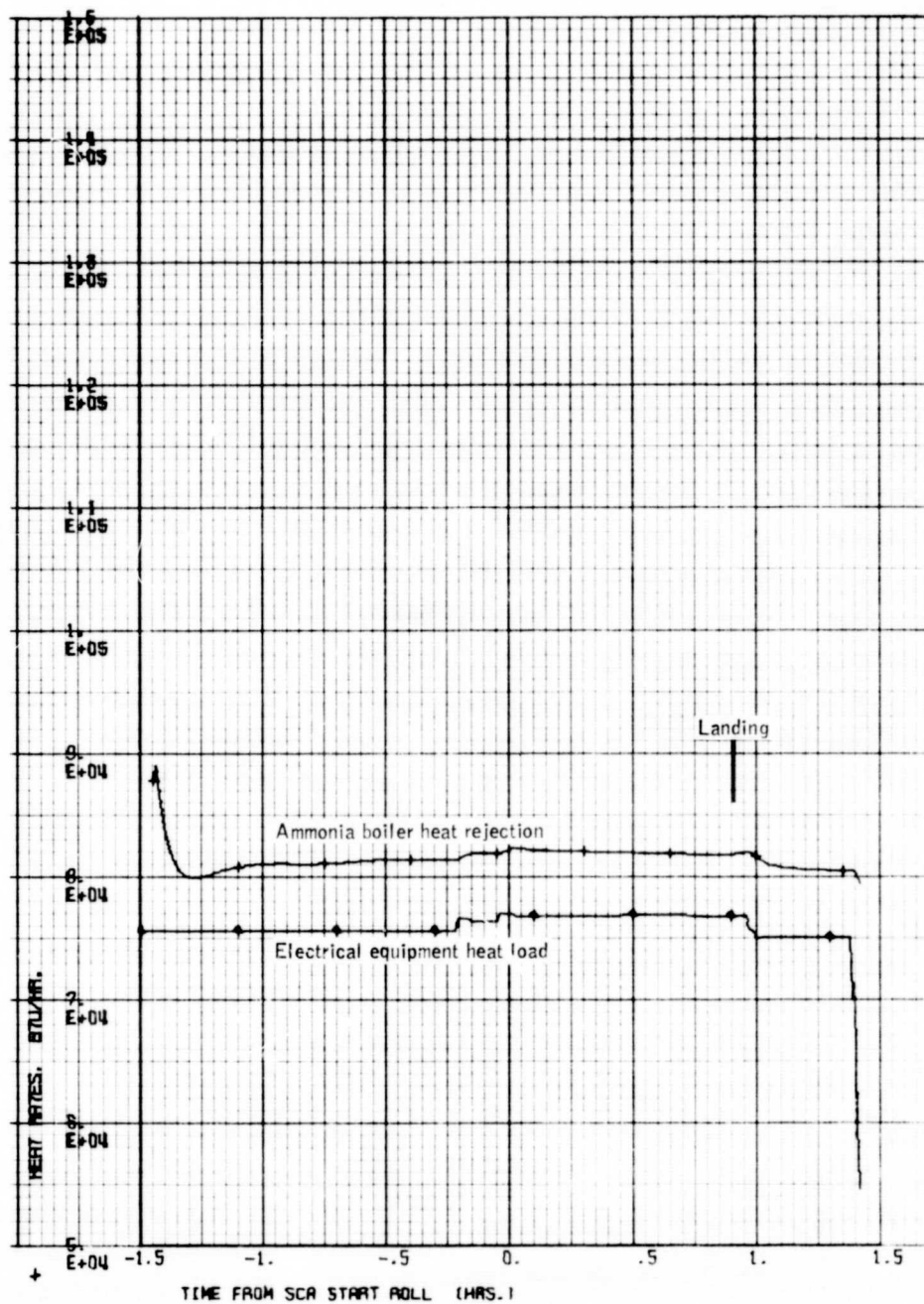


Figure 18.- Orbiter heat load and heat rejection for ALT captive/active mission 3.

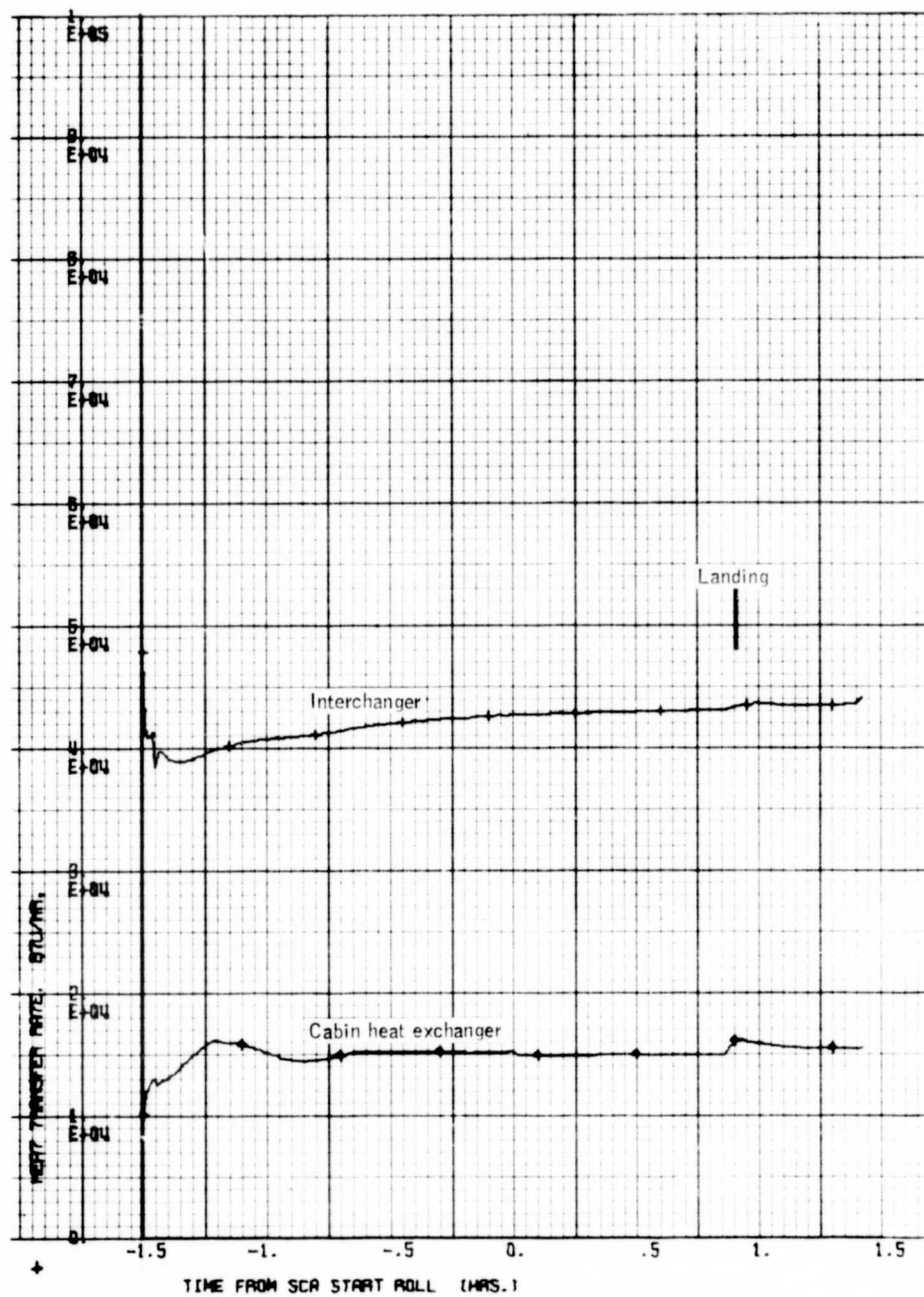


Figure 19.- ECLSS internal heat transfer rate for ALT captive/active mission 3.